ARC FLASH ANALYSIS FOR SYSTEM WITH MULTIPLE SOURCES

Multiple arc flash sources happened when protective devices tripping time varies or not open at the same time resulting in subsequent removal of short circuit sources. If the worker cannot get away from the arc flash source, then the total incident energy is sums up until ultimately cleared by the last protective device. However, of course this is just a conservative assumption since arc fault can be self-extinguished during the transition state or if the available bolted fault current was already small to sustain the arc fault.

Most grid connected renewable power plant are equipped with inverter for AC interfacing. Inverter like any other electrical component such as the transformer have also provided with unit protection. Protection like the anti-islanding is used to turn-off the inverter operation in predetermine time after the system has been disconnected from the main grid to avoid unwanted event. Typically, a time delay of 1 second is used however it can be increased/decreased further as may deemed necessary.

BESS and Wind Turbine Generator (WTG) can be assumed to have multiple sources especially when they are connected to the main grid as can be depicted in Figure 1. Without inter-trip communication link, subsequent operation of protective devices is possible which could result in varying arc fault level.

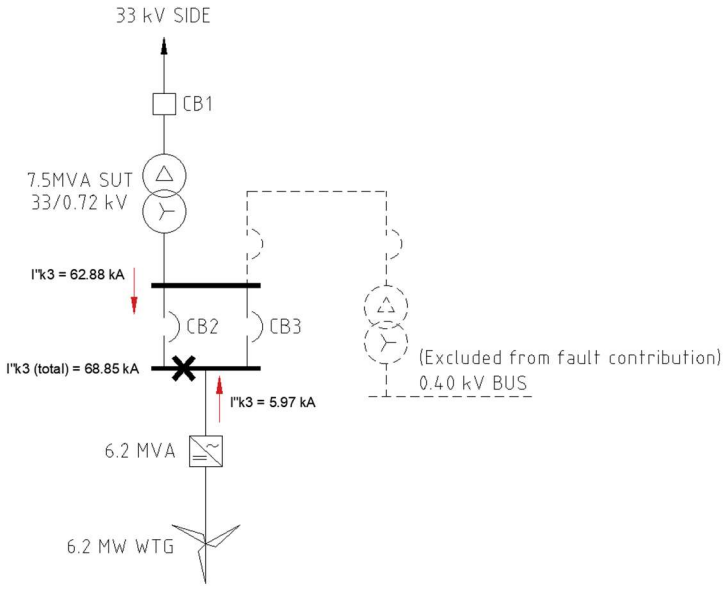

Figure 1: Key single line diagram

From above figure 1, two stages of arc fault scenarios can be seen possible. The first stage is when the arc fault is to be cleared by the upstream protective device in 1.25 seconds [Figure 2]. At this stage prior to be cleared, the total arc fault is the combined grid and WTG contributions.

The second stage of arc fault scenario is when the only source of short circuit current is solely coming from WTG. Similarly, when this happens, the converter senses no connection from the grid due to isolation from HV side. This will cause the anti-islanding protective function[1] to operate to prevent the converter from supplying power to the fault point. Typically, a delay of 1 second is use for this function, however, no specific information has been secured to confirm the 1 second hence a time of 2 seconds is assumed for the arc duration to determine the equivalent incident arc flash energy.

Below is the summary of bolted fault current contributions for the two stages. The equivalent arcing currents and incident energy levels are calculated and summarized in Table 1.

1. Stage 1 – Grid + WTG = 68.85 kA rms
2. Stage 2 – WTG = 1.2 pu* x WTG Converter FLA
   = 1.2 pu x 4972 A
   = 5.97 kA rms

* Assume converter maximum short circuit contribution = 1.2 pu x WTG Converter FLA

Arc flash parameters for this study:

Voltage	= 720 V
Pre-fault	= 100%
Working distance	= 500 mm
Electrode gap	= 33 mm
Electrode configuration	= HCB
Enclosure dimension	= 960 mm x 1555 mm x 558 mm [H x W x D]

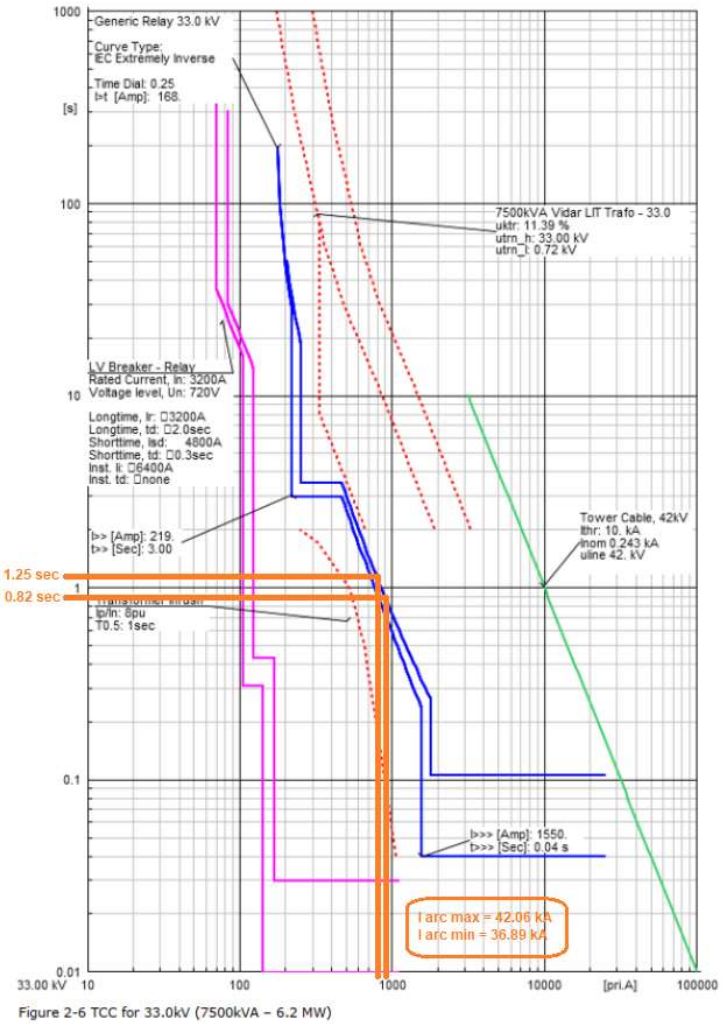

Figure 2-6 TCC for 33.0kV (7500kVA – 6.2 MW)

*Arcing currents magnitudes are based on 0.72 kV side

Figure 2: Arc duration time

Table 1: Summary of calculated values

Stages	Three phase bolted fault current	Arcing current	Arc duration	Incident energy	Incident energy [Worst-case]
1	68.85 kA [Grid + WTG]	42.060 kA (max)	0.82 sec[2]	156.011 cal/cm2	
		36.891 kA (min)	1.25 sec[2]	207.527 cal/cm2	207.527 cal/cm2
2	5.97 kA [WTG]	4.680 kA (max)	2.00 sec	37.609 cal/cm2	37.609 cal/cm2
		4.105 kA (min)	2.00 sec	32.820 cal/cm2	

[2] Approximate (indicative) combined relay and breaker time operation

From the results in Table 1, if arc flash occurs, the worker standing in front of the arc flash source will be exposed to a maximum incident energy level of 207.527 cal/cm2 based on 1.25 seconds arc duration time. However, the arc fault will continue to exist for another 2 seconds due to time delay that is set in the anti-islanding protection, yet the incident energy level will be reduced to 37.609 cal/cm2 since the only remaining source of short circuit current is the WTG.

Assumed that the worker cannot move away from the arc flash source, the total collective incident energy level will be the summation of the two calculated incident energy levels based on 3.25 seconds total arc duration time.

Total incident energy levels = 207.527 cal/cm2 + 37.609 cal/cm2
= 245.136 cal/cm2

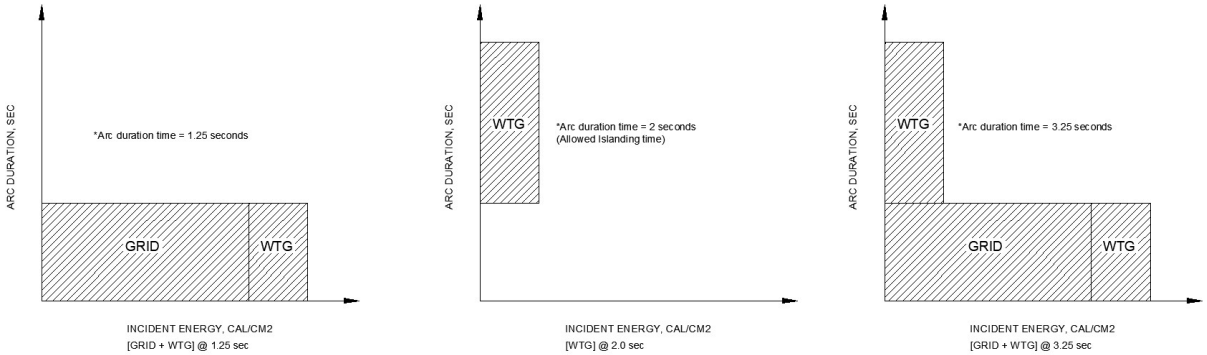

Figure 3(a) Figure 3(b) Figure 3(c)

Figure 3: Illustration of overall energy accumulation

At the onset of arc flash, both grid and WTG contributes to the arc fault location until grid supply removed in 1.25 seconds as shown in Figure 3(a) due to opening of upstream protective device. The total accumulated energy is then reduced as shown in Figure 3(b), but the WTG contribution continue for the entire period until be cleared by anti-islanding protection in 2 seconds. To sum up, the arc flash will be ultimately cleared in 3.25 seconds with an overall energy accumulation of 245.136 cal/cm2. The illustration for the overall accumulated incident energy is shown in Figure 3(c).

Unfortunately, software like ETAP cannot perform arc flash analysis for varying arc fault current. In this regard, sound engineering judgement is applied in these analyses.

According to time/motion study, human reaction time to sense, judge, and run away from a hazardous situation varies from person-to-person. However, a typical time of 0.4 second has been observed for

human reaction time. This means that 0.4 seconds is the shortest time in which a person can view a condition and begin to move or act. In all other conditions, it is not possible to see hazardous situation and move away from it, hence in arc flash analysis, the provision in IEEE 1584 for 2 seconds is a reasonable assumption for a worker to move away and shelter himself, if possible, from an arc flash hazard situation.

Therefore, if the worker can get away quickly from the arc flash source within the 2 seconds timeframe from the beginning of the arc flash, then the incident energy exposure will be reduced. This means that the worker will only be exposed to a total combined incident energy level of 245.136 cal/cm2 for 1.25 seconds [Figure 3(a)] plus the incident energy level supplied from WTG at 0.25 seconds exposure [Figure 3(b)].

Using arc flash calculator, the equivalent incident energy level supplied only from WTG at 0.25 seconds exposure is calculated to be 4.70 cal/cm2. Based on the maximum 2 seconds arc duration time, the worker will only be exposed to an incident arc flash energy level equal to 249.806 cal/cm2.

Total incident energy level = 245.136 cal/cm2 + 4.70 cal/cm2
= 249.806 cal/cm2

The total calculated energy of 249.806 cal/cm2 may be conservative, but not accurately correct since the energy is evidently decaying through the subsequent removal of sources contributing to these energies. There is also a possibility that the arc flash can be self-extinguished after the grid source is removed at 1.25 seconds. Unfortunately, upon research, there is no publication on this aspect. Nevertheless, the worst-case results must be considered to minimize the company's liability should there be an arc-flash accident in the workplace.

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